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# ESTIMATING THE COST FOR DOING A COST ESTIMATE

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*This article provides a model for estimating the cost required to do a cost estimate. The cost of the cost estimate in thousands of dollars, $C_E$, is found to be approximately given by $C_E = KC_P^{0.35}$, where $C_P$ is the estimated cost of the project in millions of dollars and K is a constant depending on the desired accuracy of the estimate, the maturity of the technology, and the cost elements included in $C_P$ and $C_E$. Our earlier work provided data for high technology projects. This article adds data from the construction industry which validates the model over a wider range of technology.*

## I. Introduction

Within the National Aeronautics and Space Administration (NASA) and other government agencies, cost overruns are a major problem, especially with today's emphasis on tight budgets. Overruns may lead to cancellation of a project. In some cases, a potential overrun may result in modifying a project to a design-to-cost task. In 1991, we completed a study on the cost of doing cost estimates for the class of projects normally encountered in the development and implementation of equipment at the network of tracking stations operated by the Jet Propulsion Laboratory (JPL) for NASA. Our goal was to develop a tool that shows the relationship between the estimated cost of a project and the amount that should be spent on doing an estimate. We hope that such a tool may help prevent or at least reduce overruns due to inaccurate cost estimates.

Our study included a literature search and actual data from JPL procurement on what others charge JPL for a cost estimate. The results of our study were published in 1992 [1] and 1993 [2]. The data derived from the study led to a useful algorithm for determining the cost of doing a cost estimate, valid for a technology-intensive (high-tech) project. The algorithm was of the form

$$C_E = KC_P^{R} \tag{1}$$

where $C_E$ is the cost of the cost estimate in thousands of dollars, $C_P$ is the estimated cost of the project in millions of dollars, $K$ is a constant depending on the desired accuracy of the estimate, and *R* appears to be an invariant constant. When we did our study for high-tech projects, the *R* value was 0.35, and we thought this value might be true for a wide spectrum of projects, but we had no verification.

In June 1995, at the 1995 American Association of Cost Engineers (AACE International) annual meeting, R. E. Larew presented a paper [3] on data from the construction industry, representing a considerably different level of projects from those we had looked at earlier. His data reflected a low-technology (low-tech) group of projects (such as construction of buildings) versus our earlier high-tech group of projects. He also calculated an *R* value of 0.35. This supports our thought that the value of *R* is constant over a wide range of projects. We have processed Larew's data and compared them with our previous article. Table 1 shows the cost of a cost estimate for projects from 1 million to 100 million dollars.

**Table 1. Cost of a cost estimate for various project sizes.**

| Estimated project cost, 1990 $M | High-tech project cost-estimate cost (JPL data), 1990 $k | | | Low-tech project cost-estimate cost (Larew data), 1990 $k | | |
|---|---|---|---|---|---|---|
| | Definitive | Budget | Order-of-magnitude | High-cluster | Mid-cluster | Low-cluster |
| 1 | 115.0 | 60.0 | 24.0 | 6.65 | 4.70 | 3.45 |
| 5 | 202.0 | 105.4 | 42.2 | 11.80 | 8.34 | 6.12 |
| 10 | 257.5 | 134.3 | 53.7 | 15.12 | 10.68 | 7.83 |
| 50 | 452.2 | 235.9 | 94.4 | 26.84 | 18.96 | 13.91 |
| 100 | 576.4 | 300.7 | 120.3 | 34.37 | 24.28 | 17.82 |

## II. The Model

The levels of cost estimates used in the original JPL article were selected to correlate with the condensed classification of cost estimates proposed by the AACE International [4]. These are order-of-magnitude, budget, and definitive. In doing cost estimates for the NASA Deep Space Network (DSN), we typically describe the classes of estimates as follows:

(1) An order-of-magnitude level of cost estimate is usually based on preliminary statements of requirements. This is done in the requirements definition stage where there is a preliminary listing of deliverables.

(2) The budgetary level of cost estimate is based on system functional requirements with at least preliminary deliverables, receivables and schedules presented by subsystem.

(3) The definitive level of cost estimate is based on a subsystem functional design where the deliverables, receivables and schedules are carefully defined and, thus, are final.

Larew's report [3] and his dissertation [5] analyzed data supplied by contractors in the construction industry. These data were broken down by Larew's analysis into three basic classes: low cluster, mid cluster and high cluster. Larew's report describes these classes of clusters of estimates as follows:

(1) The low-cluster level of cost estimate is based on very few specialties, open- and low- finish structures, simplicity in every respect and straightforward production work.

(2) The mid-cluster level involves some specialties but not excessively; reasonable and understandable contract documents; good workmanlike finish; contractor responsibility for only the work shown on plans and in the specifications; designer acceptance of responsibility for the contract documents; and contract assurance of fair, prompt, and impartial mediation of disputes.

(3) The high-cluster level involves many specialties, excessively detailed specifications and references to exotic standards, high finish, contractor responsibility to satisfy the owner's every desire, and the appearance of contractor responsibility for the errors and omissions of the designer. Table 2 shows the comparison of classes of estimates for the JPL study and Larew's study.

We have adjusted Larew's 1975 data to 1990 dollars using the NASA new-start inflation factors [6] and a 1975 wage rate including overhead for the estimator of $25 per hour. We have added Larew's data to ours [7], and present the results in Fig. 1 and Tables 1 and 3. In Fig. 1 and Table 1, we see the cost of a cost estimate as a function of project size. Note that, in Fig. 1, the slopes of Larew's data are the same as ours, i.e., $R = 0.35$. The value of $R$ seems to be independent of the type of project In Table 3, we compare $K$ values for both sets of data. The $K$ values are a function of the type of project and also the base year used for the inflation calculations This last point is a subtle one that can be overlooked. The algorithm for transforming to another year is

$$K_{XX} = K_0 * (IF_{XX})^{(1-R)} \qquad (2)$$

where $K_{XX}$ is the new value of $K$ in year 19XX, $K_0$ is the value of $K$ in the base year, $IF_{XX}$ is the value of the inflation factor [6] relative to the base year, and $R$ = 0.35. Table 3 shows $K$ values for 1990 and 1995 for which the *NASA Inflation Index* yielded $IF_{95}$ = 1.228. In the process of adjusting the cost data from one fiscal year to another, we have assumed that both the cost of doing an estimate and the cost of the project are adjusted by the direct ratio of the inflation factors for the two fiscal years.

**Table 2. Classifications of cost-estimate accuracy**

| Class | Accuracy, percent |
|---|---|
| AACE order-of-magnitude | -30 to +50 |
| AACE budget | -15 to +30 |
| AACE definitive | -5 to +15 |
| Larew low-cluster | ≈ -30 to +50 |
| Larew mid-cluster | ≈ -15 to +30 |
| Larew high-cluster | ≈ -5 to +15 |

**Table 3. Comparison of *K* values for FY 1990 and FY 1995.**

| *K*, FY 1990 | *K*, FY 1995 | Project |
|---|---|---|
| | | High-tech |
| 115.0 | 131.42 | Definitive |
| 60.0 | 68.57 | Budget |
| 24.0 | 27.43 | Order-of-magnitude |
| | | Low-tech |
| 6.6 | 7.60 | High-cluster |
| 4.7 | 7.60 | Mid-cluster |
| 3.4 | 3.94 | Low-cluster |

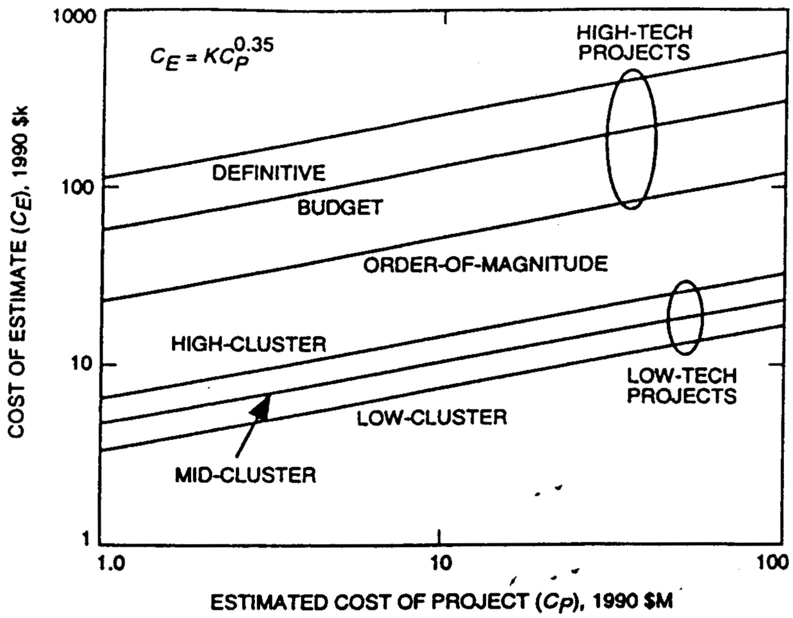


**Fig. 1. The cost of a cost estimate versus the estimated cost of a project.**

## III. Example Using The Model

Assume you have to estimate the cost required to do a cost estimate for a high-technology project that is expected, based on other similar projects, to be in the ballpark of $20 million. We will use Eq. (1) and Table 3, where $C_P = 20$; $R = 0.35$; and $K = 24$, 60 and 115 for an order-of-magnitude estimate, a budget estimate and a definitive estimate, respectively. Using $C_E = 24 * 20^{0.35}$, we get about $70,000 for an order-of-magnitude estimate. For a budget estimate, we get about $170,000, and a definitive estimate will cost about $333,000 in 1990 dollars. On the other hand, for a low-technology project, an order-of-magnitude estimate costs only about $10,000, whereas a budget estimate costs about $13,000 and a definitive estimate about $19,000 in 1990 dollars.

## IV. Summary

We previously developed a model for estimating how much should be allocated to doing cost estimates for future DSN projects to support new space missions. The addition of data developed by Larew [5] supports the use of the model over a broad spectrum of applications from high to low technology. The model may also help companies or government agencies make better cost estimates and thereby reduce the possibility of producing cost estimates that are too low, which has often been the case in the past. These low cost estimates have led to cost overruns, or the reduction of some functional requirements, or both.

The methodology presented here should be applicable over a wide range of industries. The expected value of *R* in the algorithm is 0.35. This conclusion is a key point in the applicability of this study. You can calculate the cost to do a cost estimate from Eq. (1) by using *K* values from Table 3 and Eq. (2). However, if you have a project that does not fit these categories, you can estimate *K* from Eq. (1) if you have one cost estimate $C_E$, for a specific project, $C_P$, since *R* is assumed constant at 0.35. If no cost history is available, a reasonable value of the estimated cost of a cost estimate could be obtained by interpolating from the data in Tables 1 and 3.

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## References

1) D. S. Remer and H. R. Buchanan, "A Model for the Cost of Doing a Cost Estimate," *The Telecommunications and Data Acquisition Progress Report 42-110, April-June 1992*, Jet Propulsion Laboratory, Pasadena, California, pp. 278-283, August 15, 1992.

2) D. S. Remer and H. R. Buchanan, " The Cost of Doing a Cost Estimate", *Cost Engineering*, vol. 35, no.3, pp. 7-11, March 1993.

3) R. E. Larew, "Impact of Estimating Accuracy on Markup", *1995 American Association of Cost Engineers (AACE International) Transactions*, pp EST. 1.1-EST. 1.3, June 27, 1995.

4) K. K. Humphreys, *Jelen's Cost and Optimization Engineering*, third ed., New York: McGraw-Hill, p. 370, 1991.

5) R. E. Larew, *A Quantitative Approach to Estimating and Pricing in a Construction Company*, Ph.D. dissertation, Ohio State University, Columbus, Ohio, May, 1976

6) *NASA Inflation Index*, Systems and Cost Analysis Division, National Aeronautics and Space Administration, Washington, D. C., April 19, 1994

7) D. S. Remer and H. R. Buchanan, "Estimating the Cost for Doing a Cost Estimate," *The Telecommunications and Data Acquisition Progress Report 42-125, Long-Range Planning Program, pp 1-5, January-March 1996*, National Aeronautics and Space Administration, Jet Propulsion Laboratory, Pasadena, California, May 15, 1996